



THE  
JOURNAL OF ECONOMIC BIOLOGY.

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SOME DIPTEROUS LARVAE FROM THE TURNIP.\*

By

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WITH 7 FIGURES.

IN July, and again in September, 1910, I received from Mr. A. W. Oldershaw of Dundalk, examples of curiously deformed Swede Turnips, the leaf-stalks showing abnormal swellings just above the roots, and the leaves displaying a strange crumpled and distorted



Fig. 1.—Young Swede Turnip plant deformed by Dipterous larvae.

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\* Read before the Association of Economic Biologists, Birmingham Meeting, April 6th, 1911.

[Journ. Econ. Biol., July, 1911, vol. vi, No. 3.]

aspect, which led Mr. Oldershaw to apply the appropriate name "cabbage-headed" to the affected plants (Fig. 1). The roots also were eaten away both at the crown, and at the sides, and in the worst cases there were large hollows or masses of decaying tissue in the middle of the turnip.

This damage to the root was plainly due to maggots of the common Cabbage-fly (*Phorbia brassicae*, Bouché), which were found abundantly in the material sent in autumn. The interest of Mr. Oldershaw's observation lies in the discovery of at least two dipterous insects hitherto little known or unrecognised as enemies to cruciferous crops, and worthy of further study.

#### CECIDOMYID LARVAE.

Between the bases of the leaf-stalks, which formed the swollen growths referred to above, were found larvae of a gall-midge, feeding usually six or eight together (Fig. 2). These larvae were first



Fig. 2.—Larvae of Cecid (*gen. et sp. incert.*) feeding between petiole bases of Turnips. Magnified.

noticed by Mr. F. V. Theobald,<sup>1</sup> to whom also Mr. Oldershaw had sent examples of the strangely deformed turnips, the appearance of which Theobald has illustrated by some good photographs. As regards the feeding habits of these larvae, I can do no more than confirm Theobald's account, and mention that in September I found some of them crawling over the surface of the leaves in company with the other larvae described below. Theobald was able to observe that these grubs enter the soil to pupate; unfortunately he succeeded in rearing only a single female midge, which is believed both by Mr.

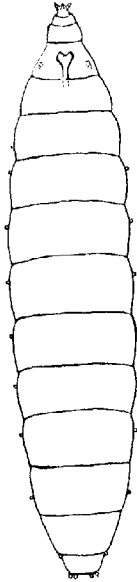


Fig. 3.—Larva of Turnip Ceid, Ventral View. Magnified 30 times.

E. E. Austen, of the British Museum, and by the Abbé Kieffer, well-known as a Continental authority on the *Cecidomyiidae*, to belong to a new species of the family. My own attempts to rear the midges were unsuccessful. It is worth while, however, to give some account of the larva.

The grub is 3 mm. long and about .65 mm. broad, of the usual

<sup>1</sup>S.-E. Agric. Coll. Rpt. Econ. Zool. for year ending September 31st, 1910, pp. 90-91, pls. xli, xlii.

cecid shape, and creamy-white in colour. The ventral "anchor-process" or "breast-bone" is very deeply emarginate in front, with prominent quadrate side-outgrowths, this front part of the anchor-



Fig. 4.—Deformed Turnip leaf, with maggot of *Scaptomyza flavicola* feeding. Magnified.

process is strongly chitinized and deep yellow in colour. The prothoracic spiracles are situated dorsally, the abdominal spiracles, as usual in the family, are lateral. At each side of the hindmost

segment are two minute rounded tubercles, the outer pair carrying short spines. (Fig. 3).

We must hope that the Abbé Kieffer will soon be able to identify this interesting insect for us. There is no doubt that the basal swelling of the shoots must be attributed, as Theobald states, to the presence of these cecid larvae between the leaf-stalks.

#### *Scaptomyza flaveola*, Meig.

The curiously crumpled leaves of the turnips under examination have already been mentioned. On the upper surface of these leaves (Fig. 4) were found both in July and in September maggots of small muscoid diptera with elongate tail-spiracles (Fig. 5). These maggots were tearing at the leaf-tissue with their mouth hooks, and there can, I think, be no doubt, that the damage to the foliage, must be at least partly attributed to their presence, though it is very likely, as Theobald suggests, that the irritation set up by the cecid larvae at the base of the shoots is not without influence on the leaves.

Some of these maggots, received early in September, pupated after a few days, and before the end of the month they had developed into flies of the genus *Scaptomyza*, which belongs to the *Drosophilinae*. There was a larger yellow species (Fig. 7), which I identified as *Scaptomyza flaveola*, Meig.<sup>1</sup> This identification has been kindly confirmed by Mr. P. H. Grimshaw, of the Royal Scottish Museum, Edinburgh, who believes the other species, smaller and dark grey in colour, to be *S. graminum*, Fall.

As these *Scaptomyza* maggots are undoubtedly injurious to turnip foliage, it is worth while to give a fuller account of their form and outward structure than has yet been published.

The maggot (Fig. 5) measures 3 mm. in length, and is of the tapering form and whitish colour usual in muscoid larvae. The head region (Fig. 5, c) shows the typical anterior processes, and the rugose areas before and behind the mouth-hooks; the latter are provided with three or four sharp teeth. Each prothoracic spiracle (Fig. 5, c) consists of seven or eight open tubes of varying lengths, which arise irregularly from a common trunk, and are clustered together like the fingers of a hand. The appearance of this spiracle differs markedly from the regular fan-like form that is familiar in the maggots of *Musca*, *Calliphora* and their allies.

A remarkable feature in this larva is the presence of numerous short spines or fine hair-like outgrowths of the cuticle on all the body-

<sup>1</sup> See G. H. Verrall, "List of British Diptera," p. 34, and Schiner, "Diptera Austriaca," vol. ii, p. 279.

segments (Fig. 5, *a*, *b*, *c*). These are most prominent on the dorsal aspect. Towards the front edge of a segment one finds minute short, stout spines, these soon give place to more elongate hair-like structures, which are arranged in fairly regular transverse rows. The hindmost segment of the larva bears four pairs of conical processes, one dorsal and vertical, two lateral, and two ventral (Fig. 5, *a*, *b*);

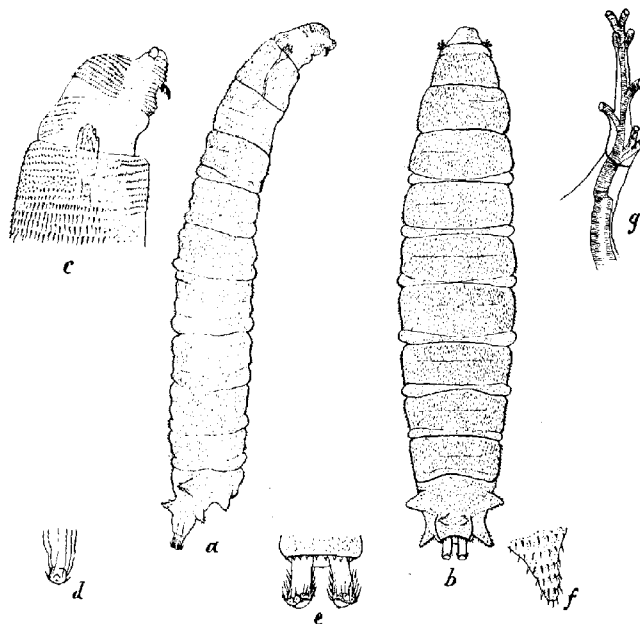


Fig. 5.—Larva of *Scaptomyza flaveola*. *a*, Side view. *b*, Dorsal view. Magnified 30 times. *c*, Anterior end, showing mouth hooks, spiracles, and armature of cuticle. Magnified 80 times. *d*, Posterior spiracle, lateral view. *e*, Posterior spiracles, dorsal view. *f*, Postero-lateral process. Magnified 80 times. *g*, Anterior spiracular process of puparium. Magnified 120 times.

these processes are beset with fine curved bristles arranged in whorls (Fig. 5, *f*). The tail spiracles are situated at the end of a pair of prominent tubes, which project from below a toothed dorsal ridge on the hindmost segment (Fig. 5, *b*, *d*, *e*). The sides of these tubes, and the circumference of their extremities are beset with numerous rather long bristles backwardly directed (Fig. 5, *d*, *e*).

The puparium of *Scaptomyza* (Fig. 6) is remarkable for the long

elongation of the prothoracic spiracles, which project on either side of the head region like stags' antlers to which the branching air-tubes give them, indeed, some resemblance (Fig. 5, *g*).



Fig. 6.



Fig. 7.

Fig. 6.—Puparium of *Scaptomysa flaveola*. Magnified 10 times.

Fig. 7.—*Scaptomysa flaveola*. Imago. Magnified 6 times.

Most students of British economic entomology will remember Curtis' description of the "Yellow Leaf Miner" of the Turnip, *Drosophila flava*, Fallen.<sup>1</sup> Curtis gives a small scale figure of the maggot of this insect, showing clearly the elongate tail-spiracular processes. He also figures the puparium and calls attention to the "two divaricating horns on its head." Curtis's *Drosophila flava* is now placed in the genus *Scaptomysa*, so that it is nearly allied to the insect whose maggot is here described.

Quite recently the larva and puparium of a *Drosophila* have been described and figured by Martelli.<sup>2</sup> They agree with those of *Scaptomysa* in the prominent tail-spiracles of the larva, and the elongate anterior spiracles of the puparium.

The two species mentioned above, *Scaptomysa flaveola* and *S. graminum*, have been recorded by Coquillett<sup>3</sup> and Chittenden<sup>4</sup> as mining the leaves of cabbage, cauliflower, and turnip in the United States. The figure of *S. flaveola* given by Coquillett, and copied by Chittenden, shows mines made by the maggots, in radish leaves. It is noteworthy that in the present case the leaves were not mined, the larvae, both in a very young stage and fully grown, being found

<sup>1</sup>J. Curtis. "Farm Insects," p. 84.

<sup>2</sup>G. Martelli. Notiza sulla *Drosophila amfeloephila*, Lw. Bull. d. R. Scuola d'Agric., Portici, 1920, vol. iv, pp. 163-179.

<sup>3</sup>D. W. Coquillett. Two Dipterous Leaf-miners on Garden Vegetables. Insect Life. (U.S.D.A.), 1895, vol. vii, pp. 381-4.

<sup>4</sup>F. H. Chittenden. Some Insects injurious to Vegetable Crops. U.S. Dept. Agric., Div. Entom., Bull. 33 (n.s.), 1902, pp. 75-77.

on the surface. Coquillett states that "five larvae sometimes occupy the same mine, and, when the leaf containing the mine is small, they usually desert it and form new mines in the adjoining leaves." Evidently the feeding habits of these larvae vary with differing conditions.

#### ***Phytomyza flavicornis.***

In the Report already referred to, Theobald states that he reared flies of this species from maggots burrowing in the petiole and mid-rib of the Dundalk Swedes. I did not find this insect. It is noteworthy that Curtis's "Black Turnip leaf-miner" is a *Phytomyza* (*P. nigricornis*).

#### SCAVENGING DIPTEROUS LARVAE.

As might have been expected, the plants which had been badly damaged and whose tissues were decaying, furnished an attractive breeding-ground for several species of Diptera whose larvae live as scavengers. Among the flies thus reared were a species of *Sciara*, *Phora rufipes*, Meig., and *Homalomyia canalicularis*, Fab. (the "Small House-fly"), whose brown maggots beset with their curious elongate processes were very common.

During the present year, I hope to have an opportunity of studying further the life-history both of the unknown cecid and of the *Scaptomyza*, and determining, if possible, the share that each takes in causing the curious distorted growth of the Swedes. Mr. Oldershaw states that this condition has been very prevalent throughout a large district in Co. Louth for the past two years. The deformed condition of the plants must indeed be distressing to the farmer. I trust to have shown that they are of no little interest to the student of the life-history of Diptera.

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# COCCIDIOSIS IN BRITISH GAME BIRDS AND POULTRY.

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WITH 2 FIGURES.

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## I.—INTRODUCTION.

SPRING is the season of rejuvenescence and of the general awakening of Nature. It is especially the season for young plants, young birds, and young mammals. To the naturalist it is a time of great pleasure for the domestic habits of parent birds, and their tiny offspring can be observed in all their beauty. To the sportsman, gamekeeper, and poultry-raiser it is, however, a period of anxiety, for on the upbringing of healthy young stock depends much of the success of the forthcoming season—whether from the sporting or the economic point of view. How many a careful keeper rejoices in fine and numerous young broods in the spring, and later is saddened at the greatly

diminished numbers that he can find. How has such a fatal dwindling been brought about? It is here that the aid of the scientist has been recently invoked, more especially in the case of the game and domestic birds, with the result that the problem of why large broods dwindle in a somewhat mystifying manner has been solved, at any rate in the case of young grouse and pheasants.

Before proceeding further, it would be well to dispel the common error made by people who speak of "the grouse disease." Like most animals, grouse—and incidentally many other birds—are beset by complications of many diseases. These may be co-existent or may occur progressively. Undoubtedly some diseases occur more commonly among young birds, while older birds may be far less susceptible to the same complaints. From the biological point of view there is no such thing as "the" grouse disease, for several diseases are known to afflict the unfortunate birds.

Prominent among the diseases of poultry is one known to the poultry-breeders variously as "white scour," "scour," "white diarrhoea," or "enteritis." The same disease afflicts game birds, and is even more fatal to them than to poultry, the domesticated conditions under which poultry exist rendering them far more amenable to treatment.

The causal agent producing the above-mentioned disease has now been proved to be a small, one-celled animal parasite belonging to the sub-kingdom Protozoa. As the parasite produces resistant spores, it is a member of the Sporozoa, and belongs to the genus *Eimeria*, formerly known as *Coccidium*; hence the malady is known scientifically as coccidiosis. It may be noted that coccidiosis is not restricted to birds, but is known to occur in many other Vertebrates, in Arthropods and in Molluscs. Coccidiosis is especially fatal to young Vertebrates.

Though the structure and life-cycle of the particular *Eimeria* (*Coccidium*) that infests the common garden centipede, *Lithobius forficatus*, has been known for some years, due to the researches of the late Dr. Schaudinn, yet the life-history of scarcely any other Coccidian has been worked out in detail until last year, when the life-history of the parasite so singularly fatal to young grouse was fully set forth by the present writer. There are many differences between the life-cycles of the parasite of the grouse and that of the centipede, and inasmuch as the former animal may be said to have a more human interest, the *Eimeria* that infests the grouse is chosen as the central subject for this brief account.

II.—OCCURRENCE OF *EIMERIA AVIUM* IN THE HOST.

*Eimeria avium*, to give the parasite its full name, is a small Protozoön endowed with a great capacity for existence under unfavourable conditions for long periods, and with an almost infinite capacity for penetrating and destroying the delicate mucous membrane lining the alimentary tract of its host. The whole food tract is not affected as a rule, but there have been cases where every part of the intestine has been literally riddled by the parasite (Fig. 1). More

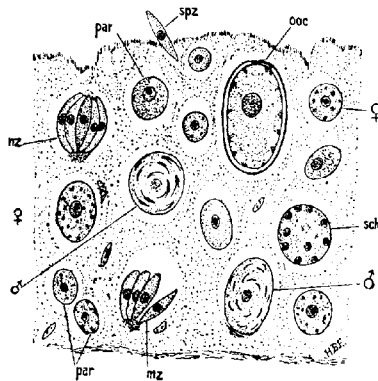


FIG. 1.—Portion of the gut (caecum) of a grouse infected with *Eimeria avium*, showing the lining epithelium riddled with parasites. Many stages in life history of *Eimeria avium* are shown in section therein.

- par = Parasite.  
 spz = Sporozoite or primary infecting germ.  
 sch = Schizont or dividing form.  
 mz = Merozoites (daughter forms).  
 ♂ = Microgametes (male elements), attached to the microgametocyte (male mother cell).  
 ♀ = Macrogamete (female).  
 ooc = Oöcyst (cyst).

Original. After Fantham, "Encyclopaedia of Sport" (1910).

particularly, however, does it infest the duodenum, that highly important part of the digestive canal where the most active digestive processes go on, and then it passes along the food canal until the long-paired caeca or "blind guts" (especially long in grouse) are reached. Here the parasite finds a most suitable environment and active multiplication occurs again, sexual forms leading to resting bodies being ultimately produced (as also in the duodenum) and the caecal walls

reduced to extreme thinness, their lumina, however, being considerably enlarged. The *Eimeria* does not appear to attack the liver or gall bladder of the grouse, nor of its other game bird victims, which I will list later, and in this respect is in marked contrast with the *Eimeria* of the rabbit, which organism has also been known to be fatal to man. However the liver of turkeys and occasionally of fowls may be infected with *Coccidia*.

### III.—SYMPTOMS OF COCCIDIOSIS IN BIRDS.

As already remarked coccidiosis is especially prevalent among young birds. The symptoms of grouse, fowls and pheasants suffering from natural coccidiosis, as well as those of captive grouse, fowl-chicks and pigeons in which the disease has been artificially induced, are identical. The birds, when early infected either by way of their food or drink, stand about more than healthy young control birds do, droop their wings and utter plaintive cries. They, however, eat and drink far more greedily than do healthy birds, but in spite of this the victims rapidly become thinner, the muscles of the breast and legs showing this to a marked degree. The loss of weight is remarkable. One instance was that of a fowl chick which I artificially infected by means of its food. It and its control sister chick weighed  $7\frac{1}{2}$  ounces each at the time of infection, but when the infected bird died two months later its weight was 5 ounces, while that of the control bird was 1lb. 6oz. Other equally striking results were obtained during the course of the investigation.

In addition to loss of weight, infected birds become markedly anaemic, the comb, wattles and cere becoming pale and bloodless. The feathering also is very weak compared with that of healthy birds; that of the legs is ragged, the quills are less rigid, the sheen on the feathers is less developed, and the replacement of nestling down by ordinary feathers is much retarded in diseased birds.

Owing to the attack of the parasite on the mucous membrane of the alimentary canal digestive troubles occur, and the faeces voided by the grouse are the best ordinary index of its condition. The soft droppings of such grouse (which are caecal in origin) are very fluid, the condition being one of diarrhoea. The dejecta are very pale, softer than usual and of a sulphur yellow colour; those of normal grouse being olive green to brown in hue. Examined microscopically, a small portion of infected faeces, diluted with water, shows myriads of small oval bodies, which are the resistant forms of the parasite, known as oöcysts (or cysts)—forms by which the infection of new hosts is readily brought about. Death from coccidiosis is often

sudden, and, a point of great importance, corpses of all diseased birds should be burned and never buried, for, as I have proved experimentally, the cysts remain infective for long periods, even for a year or more—long after the disintegration of the body of the first host. Some details may now be added regarding the life-history of this devastating parasite.

#### IV.—LIFE-HISTORY OF *EIMERIA AVIUM*.

The life-cycle of the parasite is complicated, as there are two distinct phases in its developement: (i) a phase of asexual multiplication, known as schizogony, during which there is increase in the number of the parasites in the gut-epithelium of the avian host, and (ii) a reproductive phase leading, after a sexual act, to the formation of resistant cysts and spores adapted for life outside the body of the host.

##### (a) THE YOUNG, GROWING PARASITE.

The resistant form of the parasite reaches the host in the food or drink of the latter, for the resistant cysts are scattered on the heather and in the tarns at which the grouse drink. The oöcysts reach the duodenum uninjured, and here, under the influence of the powerful digestive juices present, the hard cyst-wall is softened and allows the escape of four smaller oval bodies or spores contained within. From each of these in turn emerge two minute, active, motile bodies, the primary infecting germs or sporozoites. These measure from  $7\ \mu$  to  $10\ \mu$  in length. Each sporozoite is a small vermiform organism with a single uniform nucleus (fig. 2, A). The sporozoite is rather more pointed at one end, and secretes a small amount of mucilaginous material, which rapidly hardens, and on the smooth surface thus provided, it glides forward with a gentle undulatory movement, recalling the "billows" that pass along the foot of the snail. The sporozoite remains free only a very short time in the lumen of the gut, but rapidly passes to the wall, where it attaches itself to an epithelial cell and proceeds to bore its way inwards. Once within, the parasite curls on itself (fig. 2, B) and gradually loses its vermicular form and becomes spherical (fig. 2, C, D). It grows steadily at the expense of the host cell, and soon the latter becomes greatly atrophied, its nucleus is much displaced and the parasite lies in a clear space within the host cell. The passive, feeding stage of the organism is known as the trophozoite phase (fig. 2, D).

##### (b) ASEQUAL MULTIPLICATION OR SCHIZOGONY.

Growth continues for some time, and then the parasite prepares

for multiplication. When this time is reached the trophozoite has grown large and rounded (fig. 2, D), and is about  $10\ \mu$  to  $12\ \mu$  in diameter, the nucleus has become large and contains chromatin in a more or less compact mass or karyosome. The nucleus proceeds to divide into a number of portions that travel outwards and finally become disposed in a zone at the periphery (fig. 2, E) of the parasite. The organism in this multinucleate condition is known as a schizont. Protoplasm collects around each nucleus (fig. 2, E, F), and the result is the production of a group of daughter individuals (fig. 2, G)—the merozoites. Each vermiform merozoite is from  $6\ \mu$  to  $10\ \mu$  long and greatly resembles a sporozoite, but differs from the latter in that its nucleus contains a minute dot of chromatin—the karyosome. The merozoites of a group are arranged "en barillet" (fig. 2, G), much like the segments of an orange.

The merozoites separate from one another (fig. 2, H), and each one is capable of infecting another epithelial cell of the gut-wall of the avian host, and does so. The processes of growth and multiplication are repeated until the duodenal lining is reduced to an almost structureless mass (fig. 1). The number of merozoites formed from each schizont seems to vary; 8 to 14 appear to be common numbers, but as many as 20 merozoites have been found to be produced by a single schizont. The process of formation of merozoites is known as schizogony.

In most cases, some of the merozoites pass down the lumen of the gut and reach the caeca, where they proceed to penetrate the lining epithelium, round off and multiply by schizogony as in the duodenum. Probably coccidiosis set up in the duodenal wall is sufficient to kill very young birds; for example, grouse chicks from 8 to 10 days old, while older chicks, dying at the age of 4 to 6 weeks, may have partially recovered from duodenal coccidiosis and succumb to coccidiosis in the caecum (typhlitic coccidiosis). In the case of intense duodenal coccidiosis I have found free merozoites in the intestinal contents and even in freshly shed faeces.

It is of great importance to note that the period of schizogony of the parasite is the most critical time for the infected bird, for during this period there is derangement of the digestive processes and acute inflammation of the intestines (enteritis).

#### (c) GAMETOGENY.

After several generations of merozoites have been produced, both in the duodenum and caecum, a limit is reached both to the multiplicative power of the parasite and to the capacity of the host to provide

the invader with nourishment. Consequent on this, the parasite begins to prepare for extra-corporeal life and to produce sexual parasites by whose union resistant forms result. Two forms of parasites now are produced. The one form is large and contains much granular food material (fig. 2, 1 ♀). This type of organism is destined to become the female mother cell or macrogametocyte. The second form is slightly smaller than the first, and is far less granular (fig. 2, 1 ♂). Like the macrogametocyte it is more or less oval in shape. But whereas the female mother cell gives rise to one female cell or macrogamete only, the male mother cell or microgametocyte will produce ultimately a very large number of minute, biflagellate, active microgametes or male cells (fig. 2, 8 ♂).

The processes leading to the formation of the male and female gametes is termed gametogony.

#### THE MACROGAMETOCYTE AND MACROGAMETE.

The macrogametocytes or female mother cells really are modified schizonts whose growth is slow, and hence they are able to accumulate much reserve food material within themselves. When full-grown they are from  $11.8 \mu$  to  $17.5 \mu$  in length, by  $6 \mu$  to  $11 \mu$  in breadth in section. In the richly granular cytoplasm are two kinds of granules (fig. 2, 1 ♀, 8 ♀). One variety of granule is much more stainable than the other, and is known as the chromatoid granule, while the other kind, well seen in life, forms large, roundish, refractile masses appearing yellow or greyish green in fresh preparations. These are known as plastinoid granules.

As the parasite grows, the plastinoid and chromatoid granules travel towards the periphery, and at this period a cyst wall is formed around the macrogamete (fig. 2, 8 ♀). The use of the chromatoid granules is then seen, for they pass out and form part of the inner layer of the cyst wall. The formation of the cyst takes place while the parasite is still within the epithelium of the host. Hence the macrogamete encysts precociously, but a thin spot or micropyle is left in the cyst wall, and by means of this pore the microgamete or male cell can enter at the time of fertilisation.

#### THE MICROGAMETOCYTE AND MICROGAMETES.

The microgametocyte or male mother cell is an ovoid cell about  $13 \mu$  long and  $8 \mu$  broad as seen in the sections that I have examined. The formation of the numerous microgametes (male parasites) from it is interesting. The chromatin of the nucleus at first is concentrated in the karyosome, but it soon breaks up into a number of minute granules of chromatin, called chromidia, which travel outwards to

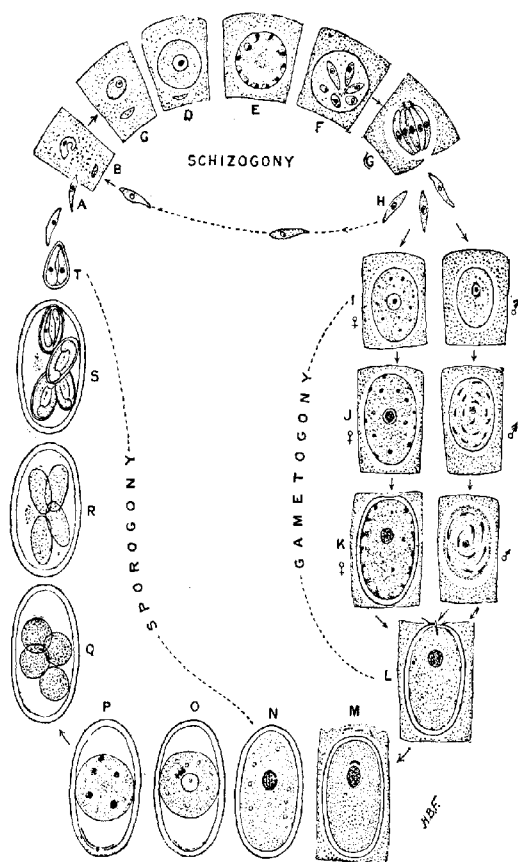


Fig. 2.—Diagram of Life-cycle of *Eimeria (Coccidium) avium*.  
(Original. After Fantham, from Proc. Zool. Soc., 1910, p. 684).

Fig. 2.—B-H. Illustrate the asexual reproduction (schizogony) of *E. avium*. Epithelial host cells diagrammatically outlined.

Fig. 2.—I-L. Illustrate the production of sexual forms (gametogony).

Fig. 2.—N-T. Illustrate spore formation (sporogony).

- A. Sporozoite or primary infecting germ which penetrates the epithelial cell of the duodenum of the host.
- B. Sporozoite curving on itself before becoming rounded within the host cell.
- C. Young, growing parasite.
- D. Fully grown parasite. (Trophozoite).
- E. Schizont, with numerous daughter nuclei peripherally arranged. (Seen in transverse section).
- F. Schizont, showing further differentiation of merozoites.
- G. Merozoites arranged "en barillet," about to issue from the host cell.
- H. Free merozoites.
- I. ♀ Young macrogametocyte with coarse granules.
- J. ♂ Young microgametocyte with fine granules.
- J. ♀ Growing female mother cell, showing chromatoid and plastinoid granules.
- J. ♂ Microgametocyte with nucleus divided to form a number of bent, rod-like portions, the future microgametes.
- K. ♀ Macrogamete which has formed a cyst wall for itself but left a thin spot for the entry of the microgamete.
- K. ♂ Microgametocyte with many biflagellate microgametes about to separate from it.
- L. Fertilisation. One microgamete is shown penetrating the macrogamete, while other male cells are near the micropyle but will be excluded.
- M. Fertilisation. The male pronucleus is lying above the female chromatin. Degenerating microgametes are shown outside the oöcyst.
- N. Oöcyst (encysted zygote) with contents filling it completely.
- O. Oöcyst with contents concentrated, forming a central, spherical mass. Many such cysts seen in infected caecal droppings.
- P. Oöcyst with four nuclei.
- Q. Oöcyst with contents segmented to form four, rounded sporoblasts. (As seen in fresh preparations).
- R. Oöcyst with four sporoblasts which have grown oval and are becoming sporocysts.
- S. Oöcyst with four sporocysts, in each of which two sporozoites have differentiated.
- T. Free sporocyst in which the sporozoites have assumed the most suitable position for emergence.

the surface of the microgametocyte, where they form a very fine network. The chromidia then collect into small groups or patches arranged in the form of minute irregular loops with central hollows. The chromatic loops form a number of flexible rod-like bodies (fig. 2, j  $\delta$ ), composed almost entirely of chromatin. When completely formed, the minute male parasites are only about  $3\mu$  to  $4\mu$  long (as measured in section), and the chromatin of their bodies is surrounded by a film of their protoplasm prolonged outwards to form two extremely fine flagella (fig. 2, k  $\delta$ ). One flagellum trails behind the body, of which it is practically a continuation, while the other is anterior.

The microgametes gradually separate from the mother cell, of whose body a large proportion remains unused. The microgametes, when free, move about in the lumen of the gut with a gliding serpentiform movement, but it is only with the greatest difficulty that they can be distinguished as they move among the epithelial and food debris and the other fauna of the gut of the host.

#### (d) FERTILISATION.

This process has been watched in life. When the macrogamete has attained its maximum development, it often comes to lie close to the lumen of the gut, with its micropyle directed outwards.

Sometimes the macrogamete ( $\sigma$ ) bursts through the wall and lies free in the lumen of the gut. Meanwhile the microgametes ( $\delta$ ) break free from their parent cell and swim out with rapid lashing of their flagella into the gut, where they are attracted, possibly by some chemiotactic substance, towards the female gamete. The minute microgametes swarm around the micropyle (fig. 2, l), and several have been seen vigorously endeavouring to enter at one time. One at length succeeds, and appears spirally to bore its way into the macrogamete, whose nucleus moves up to meet it (fig. 2, l), and finally is lost to view. The macrogamete at once secretes a plug of protoplasm that blocks the micropyle and excludes the other microgametes that finally degenerate.

The macrogamete, as before mentioned, is heavily laden with food granules, and these make it difficult to follow the subsequent details of fertilisation. There are indications of the formation of a small fertilisation spindle at times (fig. 2, n), but the nature of the material frequently prevented observation of this structure. When fusion of the nuclei of the two gametes (fig. 2, m, n) is accomplished, a zygote is formed, and the latter—inside its cyst (oöcyst)—proceeds to spore formation or sporogony.

## (e) SPOROLOGY.

The onset of sporogony of *Eimeria avium* usually means either the recovery or the death of the infected chick. When the infection has not been acute, the oöcysts pass from the body, and the internal gut-lining may be able to regenerate and the bird gradually regains weight. Sometimes infiltration of connective tissue into the lesions formed by the parasite aids in this recovery. But when the attack is acute too much gut-epithelium is destroyed, and owing to complications arising therefrom the bird dies.

The oöcyst at first has granular contents with a yellowish or greyish appearance. The contents then completely fill the cyst (fig. 2, N), but after a short time they shrink away, so that it is common to find oöcysts with a central mass (fig. 2, O). But this does not obtain in every oöcyst, for some are found with the contents nearer one pole than the other. The central position of the contents is much the more common in the *Coccidium* of the grouse, while the asymmetric position is usual in the nearly allied parasite of the pheasant.

Whatever the shape of the oöcyst, the changes that follow take the same course. The nucleus (synkaryon) of the zygote divides directly first into two and then into four, the divisions following one another rapidly (fig. 2 P). Around each of these nuclei the general cytoplasm segregates, with the result that four rounded bodies now are present inside the oöcyst (fig. 2, Q). Each of these bodies is the precursor of a spore, and is termed a sporoblast. After a time the sporoblasts become oval (fig. 2, R), and each invests itself with a cell wall (sporocyst) and forms a uninucleate spore.

The development of spores usually goes on when the oöcyst is outside the body of the host and the dejecta of infected grouse chicks contain myriads of oöcysts in various stages of development. But, in the acute cases of coccidiosis, it is possible to find oöcysts with fully-developed sporocysts actually within the wall of the gut as well as lying free in the lumen of the caecum.

The further development of the spores is largely determined by the conditions under which they are placed. Ordinarily the oöcysts develop sporocysts in about three days, at room temperature (fig. 2, S).

On the moors the dejecta of the grouse gradually crumble into a fine dust, which is disseminated by the wind over the heather and into the tarns at which the birds drink. The oöcysts can retain their vitality and infectivity for very long periods—over a year. I

have shown experimentally that some uninucleate oöcysts, kept in a mass of grouse faeces, have developed their four sporocysts eighteen months after they were collected. On the heather and in the water on the moors are thousands of oöcysts. Should a grouse eat some of the heather the oöcysts are ingested with it, and pass unharmed through the gizzard of the bird into its intestine, the heat of the bird's body meanwhile accelerating the formation of sporocysts, should the sporocysts not have been already formed in the ingested oöcysts. In the duodenum, under the influence of the pancreatic juice, the oöcyst wall softens, the four sporocysts emerge (fig. 2, s, t), and in turn there issues from each two small, vermiform, young parasites, the primary infecting germs or sporozoites (fig. 2, a).

The mode of formation of the two sporozoites within each sporocyst is somewhat complicated. In the fresh condition two shining vacuoles, often centrally placed, appear in the sporocyst contents. These vacuoles gradually extend and finally coalesce to form one vacuole, the greater part of the cytoplasm being arranged around the one vacuole, that is, at the poles of the sporocyst. The nucleus of the sporocyst at the same time divides into two, and one daughter nucleus passes to each pole. Gradually the protoplasm arranges itself around each nucleus in the form of a long, somewhat sickle-shaped sporozoite, the two being arranged tête à tête within the sporocyst (fig. 2, s). This arrangement is altered later, for when the sporozoites are ready to issue from the sporocyst they move so that their broad ends lie near one another, their narrow ones pointing to the weakest spot in the sporocyst wall through which they ultimately emerge (fig. 2, t, a). The sporozoites proceed to penetrate the epithelium of the duodenum of the host, where, owing to the destruction by them of the epithelium, grave digestive troubles are set up. Inflammation and diarrhoea occur, and the host, consequent on mal-nutrition, becomes emaciated, and, unless it is able to react with sufficient vigour upon the parasites, ultimately succumbs.

*Variations in Oöcysts.*—While the majority of the oöcysts are typically oval, yet variations occur, not only of size, but also slightly of shape. The size of the oöcysts varies from  $25\ \mu$  to  $35\ \mu$  long by  $14\ \mu$  to  $20\ \mu$  broad. But from my investigations I am forced to conclude that size is merely a factor of environment, and the amount of nutriment available for the parasite (macrogamete). Wherever a heavy infection of *Eimeria* occurs the parasites are crowded, they do not get as much food as where they are few, and their growth consequently is both slower and more restricted. Where abundant nourishment and space are available the oöcysts are larger.

Shape again is a factor of the environment. Mutual compression, or lack of space for development, produces variations. Sometimes the oöcysts are not oval, but sub-spherical. These are from  $18\mu$  to  $20\mu$  in diameter. Somewhat pyriform or egg-shaped oöcysts also are found, such being intermediate between the oval and sub-spherical forms.

Again, among the oöcysts of *Eimeria avium* some may be found with somewhat squarish ends, while others have a slight depression at the apex. But in every case, the further internal development follows exactly on the same lines.

*Period of Life-Cycle.*—From experiments made by feeding fowl chicks with Coccidian oöcysts, I conclude that schizogony takes from four to five days. Gametogony then occurs. Uninucleate oöcysts mature their sporocysts in two to three days. The period for the total life-cycle of the parasite is from eight to ten days.

#### V.—NOTES ON THE CONDITION OF THE INTERNAL ORGANS OF INFECTED BIRDS.

In the case of grouse infested with *Eimeria avium* the parasite is restricted to the intestinal tract, and especially to the walls of the duodenum and caeca. The blood-vessels of the intestine become engorged with blood, and inflammatory areas mark the points of most heavy infection by the parasite. The gut-contents contain much degenerated epithelium, which is particularly abundant in regions where active schizogony and gametogony are proceeding. In many cases the intestinal walls, particularly those of the caeca, become extremely thin and almost transparent. In other cases this effect is not so marked.

The large intestine also may show inflammatory patches, and blood has been found in the rectal contents. The rectum itself is but rarely attacked, though oöcysts occur in its lumen.

Examination of kidneys, spleen, liver and gall-bladder of infected grouse has yielded negative results. Occasionally oöcysts were found in the trachea, bronchi and bronchioles of the lungs of grouse, and it is probable that they had reached that position by passage of food into the trachea instead of the oesophagus.

Careful examination of the genitalia of both grouse and fowls has hitherto failed to show coccidiosis of these organs. Some investigators, however, have suggested that the eggs of fowls may be infected with Coccidian oöcysts and the young birds be born infected. Such does not appear to be the case with grouse and fowls that I have examined, but there is always the possibility of eggs

becoming contaminated during their passage through the cloaca of the mother bird by Coccidian oöcysts sticking to the egg-shell. Unless suitable precautions are taken in such cases the young chick is hatched in contact with infected material and is in a suitable position to acquire the disease by the mouth during its first feed.

In coccidiosis of fowls the intestine is the chief seat of infection, but the liver is occasionally infected with *E. avium*, as in turkeys. In the coccidial disease very prevalent in some parts of America among turkeys and known as "blackhead," a large proportion of the birds suffer from coccidiosis of the liver, as well as of the intestine. In this case when the infection is fairly heavy, the liver shows a number of rounded, yellowish patches, which are separate at first, but later become confluent and form huge necrotic masses. This infectious enterohepatitis—as it has been called—is more marked in older turkeys than in turkey poults, and pathological changes and enlargement in the liver occur in nearly all the chronic cases. It has been stated that coccidiosis of the oviduct may occur in turkeys suffering from "blackhead," but so far the evidence in support of this view is somewhat meagre, the condition mentioned appearing to be rather uncommon.

Young turkey poults succumb to intestinal coccidiosis alone. The duodenum of the infected birds presents much the same appearance as that of the grouse, but in turkeys the caeca are often thickened and distended with pasty contents; while in the grouse the caeca often become thin-walled, due to great destruction of the lining epithelium.

A reflex of coccidiosis is seen in the blood of the infected grouse and fowls. These birds become markedly anæmic, and there is an alteration in the relative numbers of the blood elements, particularly of the leucocytes. Infected birds show an increase in the number of polymorphonuclear leucocytes compared with the number found in the blood of normal birds.

The rôle of various bacteria in coccidiosis may be noted. Many bacteria are always present in the alimentary tract, and so long as they are confined to the lumen thereof they are mostly harmless. But the Coccidia, when penetrating the epithelial cells of the intestines, may act as inoculating needles and admit bacteria into the tissues of the host with disastrous results.

#### VI.—THE DISSEMINATION OF COCCIDIOSIS.

The various methods whereby coccidiosis is spread from bird to bird and from one estate to another have been investigated in the cases of infected grouse, pheasants, fowls and pigeons by the present

writer, while other workers have mentioned the droppings as the only source of infection. Coccidiosis spreads with remarkable rapidity, and undoubtedly the faeces of infected birds are the chief source of contamination. The droppings gradually crumble into a fine dust, that is distributed in the main by the wind over considerable tracts of country. This dust contains numbers of oöcysts in all stages of development. Deposited as they are on the food plants of birds, such as grouse, they are easily ingested, and the parasite recommences its life-cycle in the new host.

Water also is an agent of infection. I have collected Coccidian oöcysts from the tarns at which grouse chicks drink, and have shown experimentally that even 40 days' exposure to the action of water does not kill the encysted parasite. Again, from the dew collected off the heather in Scotland, I have been easily able to recover oöcysts in practically their full maturity.

Rain has a great share in causing local contamination of both soil and water, the latter more especially. After heavy rain the dejecta of infected birds are dispersed and washed down to lower levels of land, where the contaminated water either forms pools or soaks into the soil.

Grouse that are infected have very fluid droppings, and it has been possible sometimes to track the birds through the snow by the trails left by them on their way to their drinking places. When it is remembered that young birds are far more susceptible to coccidiosis than older ones, the question of providing uncontaminated food and drink becomes of the utmost importance.

Again, it has been my experience to find adult birds that have become chronics. They are then veritable reservoirs of infection and a prolific source of danger to young and old birds alike, at all times of the year, and from year to year. I may mention here, as being of great economic importance, that fowls suffer from the same form of coccidiosis as the grouse and pheasant, and that infected hens used as foster-mothers have been definitely tracked as the instruments for the commencement of heavy epizootics. This has been particularly the case in dealing with outbreaks among pheasants. In such cases the remedy is obvious—the carrier of infection must be destroyed and the corpse must be burned and never buried. If burial is resorted to, the oöcysts (resistant forms of the parasite) are merely put into the soil with the carcase, and there is more trouble in store when the oöcysts reach the surface and a new epizootic breaks out, often with renewed vigour.

The mutual infection of such birds as turkeys, fowls and pigeons

frequenting the same or neighbouring soiled grounds, even after the lapse of a year, should be mentioned here. It is discussed further in Section VIII. (pp. 91-94).

In Nature wind and rain are not the sole agents of dissemination of coccidiosis. There are numerous coprophagous flies, such as *Scatophaga stercoraria*, whose eggs and larvae develop in the droppings of infected birds. Such larvae and flies from grouse droppings have been most carefully examined by me, after taking every precaution to avoid external contamination of the bodies of the flies. Yet in the intestines of these flies and their larvae unchanged Coccidian oöcysts occurred, and they were also found in the dejecta of the flies voided during examination. Here, again, is a fruitful source and agent of infection on the moors, especially where there is a vigorous insect population.

To sum up, wind and rain are the most powerful agents in the dissemination of coccidiosis over tracts of country, and their action is aided by that of coprophagous and other flies found in the neighbourhood, infected droppings being the source of supply of the Coccidian cysts.

#### VII.—DURATION OF VITALITY OF COCCIDIAN OÖCYSTS.

The duration of vitality of the oöcysts and spores of *E. avium* is a matter of considerable practical importance. It is vital to the healthy development of young birds that they should not be raised on soil contaminated by their diseased predecessors, for after even considerable intervals such ground is still infected. With the object of aiding those engaged in the raising of young birds, I have made a series of experiments relating to the time during which the Coccidium can retain its vitality and power of infectivity under varying conditions.

Faeces from infected grouse were kept under different conditions approximating as far as possible to the natural ones, and the results carefully noted.

Coccidian oöcysts, with undifferentiated contents, were kept in water at about 20° C. Ordinarily the oöcysts develop sporocysts very rapidly—within two to three days. But in cysts kept in water a period of nine days elapsed before any development occurred. At the end of that period, a few oöcysts showed differentiated sporoblasts and still fewer showed four sporocysts. Two days later many more oöcysts contained sporocysts, and this progressive development continued for some days. Scarcely any signs of degeneration were seen until about the fortieth day, when

some showed signs of gas bubbles in their interiors. Others, however, had completed their development, and the sporocysts, apparently unharmed, were in some cases set free into the liquid. By the fiftieth day all the oöcysts had either matured or degenerated, and some of the sporocysts had begun to deteriorate.

When oöcysts were kept in much colder water I found that the development of sporocysts was retarded for a longer period. Further, very damp air has a similar effect to exposure in water.

When freshly voided soft grouse droppings, containing Coccidian oöcysts, are allowed to dry, the oöcysts in the surface layers rapidly develop sporocysts, the inner ones remaining unaffected.

Faeces kept *en masse* in dishes for as long as twelve months have retained the power of infecting birds, as I have been able to prove experimentally. Such material still contained undifferentiated oöcysts, while the outer layers mainly contained oöcysts with four sporocysts within them.

I now have infected faeces from young grouse received nearly two years ago. Recently some was spread into a thin layer and examined microscopically. Some undifferentiated oöcysts were seen, but four days later the oöcysts had nearly all developed four sporocysts, and so had retained their power of infectivity for nearly two years.

For experimental purposes, it was sometimes necessary to delay the development of sporocysts. This was easily done. The infected dejecta were transferred to a chamber kept at 10° C, having previously been kept at 15° C. Further development of oöcysts and sporocysts was thus retarded for a considerable time. Smaller changes of temperature also arrested the development of sporocysts, though the effect, naturally, was not so marked.

#### VIII.—SOME PREVENTIVE MEASURES AND SUGGESTIONS FOR TREATMENT.

Inasmuch as the hosts of various pathogenic *Eimeria* are game birds little can be done in the way of direct treatment, though the same remark does not apply to domesticated or even "game" birds in captivity, as in pheasantries. The old saw that prevention is better than cure can, however, be realised to some extent. Even in epizootics among game birds it cannot be too strongly insisted upon that *all corpses should be burned and not buried*. Every buried bird is a new source of infection, and the polluted soil is distributed in many and unseen ways by earthworms, the round worms of the soil,

carnivorous beetles, flies, moles, etc., so that the infection can be extended over a much wider area than was originally the case.

Again, in the case of pheasantries, in which havoc has been made by coccidiosis, it is as well to consider the direction of the prevailing winds and to place the new rearing pens in such a position that they are not windswept from the infected and fouled areas. This is not an easy matter in many cases, but should be observed wherever possible.

In dealing with coccidiosis in grouse, heather-burning is most efficacious in destroying oöcysts. Unfortunately heather is rather slow growing, and in consequence the remedy of heather burning is somewhat restricted in its area of application.

In the case of birds either partially or entirely under domesticated conditions (*e.g.*, fowls, hand-reared pheasants, grouse in captivity) great care should be taken to burn all infected droppings, and to prevent fouling of food and drink as far as possible. This can be achieved to a considerable extent by providing movable boards on which food and drink can be placed. These boards can be removed and thoroughly cleansed, while the pens should be so constructed that easy cleansing can be done daily. Lime-washing of all coops, etc., once a week is useful. Wherever possible healthy birds should be taken off the infected areas, and their coops, etc., placed in new positions as remote as possible from the former ones. The fouled soil should then be thickly treated with quicklime, which, after an interval of about a week, should be well dug into the soil, the latter being turned to a depth of at least  $1\frac{1}{2}$  feet. No birds should be raised on this land for at least a year. Where the infected run is relatively small, the top soil can be taken off to a depth of three or four inches and then burned. Even under this condition it is advisable to lime the soil.

It is useless to remove *heavily* infected stock to fresh places, for it is far better to destroy such birds and to place healthy stock on fresh, unpolluted ground. All other suspected birds should be isolated, and careful examination made of their excrement. In the case of epizootics among fowl chicks, one recent experience of mine was that of a case where over fifty birds died in a very short time of undoubted coccidiosis. Tracing the history of the remainder I found that they had come from broods reared by handsome hens obtained from an estate where, on enquiry, I found there had been heavy mortality the previous year. The foster-mothers were all carefully isolated, and examination made of their faeces from day to day. In a very few days, two fine hens were discovered whose

dejecta showed daily crops of oöcysts of *E. avium*, and I do not think there is any doubt that these two birds had become chronics and that their excrement had fouled the large grass run, and was the source of the trouble among the young birds. It may be added that the washings of the grass and clover in the run also yielded the oöcysts of the parasite when examined microscopically.

Fowls and turkeys should never be reared on grounds where much mortality from white diarrhoea or blackhead has been known to occur. If the original occupants of the land were turkeys, the oöcysts of *E. avium* producing "blackhead" are present in the soil, and when taken up with grit, food, or drink by fowls, produce the coccidiosis popularly known as "white diarrhoea," especially in young fowls. Conversely, fowl coccidiosis can be the source of infection of turkeys. Pigeons, feeding in infected fowl yards, themselves become infected, and whole cotes have been wiped out by coccidiosis thus acquired.

Wherever possible eggs should be disinfected before they are set for hatching. A solution of 90 to 95 per cent. alcohol (strong methylated spirit will do) has been recommended for wiping the eggs and found efficacious. Eggs should be carefully dried after the application.

With regard to treatment, it is almost impossible to give any advice in the case of wild birds. Any condition that tends to raise the vitality of the chicks is of service and should be used. Experiments are still in progress with regard to the treatment of infected birds in captivity.

Recently I have completed and extended some experiments on the treatment of avian coccidiosis by means of catechu. The procedure may be briefly indicated. Ten to fifteen grains of *crude* catechu are dissolved in one gallon of water. The dark sherry (or ale) coloured solution so obtained is administered to the birds as drinking water. The solution often darkens in the air, but its usefulness is not impaired thereby. The birds drink it with avidity and rapid improvement follows. The treatment is usually only necessary for about ten days. A solution containing ten grains of catechu per gallon is strong enough in most cases. The birds successfully treated were fowls, ducks, pigeons, hand-reared pheasants and grouse in captivity. The treatment, successfully determined by laboratory experiments, was tried on a small scale with infected birds on a small, covered, earth run, and on a grass run, and has been very successfully applied, at my suggestion, on several large poultry farms where heavy

mortality through coccidiosis has occurred in previous years. Although the objection might be raised that catechu is merely an astringent, yet the great success of the treatment up to the present justifies me in bringing it before the notice of the scientific agricultural public.

During the course of my investigations experiments were made with other chemical substances. Ferrous sulphate (10 grains to the gallon), introduced into the drinking water of penned birds, was of service as tending to raise the general tone of vitality of the birds and so render them able to resist the action of the *Coccidium* to a greater extent. Sodium salicylate had a similar effect. These substances were also used in experiments directed towards the destruction of oöcysts and proved of some service. Infected faeces mixed with quick lime were rapidly caked, and hence the spread of the cysts was prevented to a great extent. The cysts were ultimately burst by the quick lime and so rendered innocuous. Gas lime and slaked lime are somewhat less efficacious. When sodium salicylate was used in the place of quicklime, the mixture of salicylate and faeces rapidly liquefied. A somewhat similar effect was produced by mixing ferrous sulphate with the faeces. Ultimately the oöcysts became wrinkled and cracked and the contents destroyed, but the process took much longer than in the case of quicklime.

Nitrate of soda acts on oöcysts after a lengthy exposure. It might be of service indirectly, for when scattered on the land it is a valuable stimulant to plant growth, and so might ensure a supply of healthy young vegetation.

It is of interest to note that grouse moors situated near the sea and swept by "salt" winds seem almost free from coccidiosis as well as other diseases of grouse, while inland moors are more susceptible to the ravages of disease.

#### IX.—SOME OTHER COCCIDIA AND THEIR HOSTS.

Much of the foregoing part of the paper has dealt with the life-history of *E. avium*, a *Coccidium* pathogenic to grouse, fowls and pigeons alike, and communicable from one to the other without alteration of its morphology. But *E. avium* is but one member of a fairly large group of parasites, enjoying a rather wide distribution.

It is not intended to attempt to give here a complete systematic survey of the Coccidia, but rather to indicate a few members of the group that appear to have specially interesting features or are of economic importance.

The parasite of coccidiosis in pheasants is very like *E. avium* of grouse, and has equally fatal effects.

The parasite of "blackhead" in turkeys is *E. avium*, and the disease can be transmitted to fowls. The *Amoeba meleagridis* of Smith, formerly said to be the causal agent of blackhead, is now generally considered to be a stage in the schizogony of *E. avium* in turkeys.

*E. pfeifferi* (Labbé) is allied to *E. avium*, and may be naturally pathogenic to pigeons. Apparently the same parasite occurs in the common English sparrows (house, tree and hedge varieties), the parasites being found sometimes in small, sometimes in large numbers. The organism is widely distributed among sparrows in England and a somewhat similar parasite infests sparrow-hawks, owls, chaffinches, greenfinches, thrushes, and blackbirds, though to a less extent. I believe that I have good evidence to show that the sparrow is the carrier of infection, and that the other bird hosts named acquire the oöcysts via their food, which becomes contaminated by the dejecta of sparrows. I hope to publish in greater detail on this subject in the near future.

Ducks and geese are liable to coccidiosis to some extent. Coccidiosis in quail has been reported in America.

Marine birds, such as gulls, guillemots, choughs, etc., are very liable to coccidiosis, but an *Eimeria* is not the causative agent of their complaint. Coccidia belonging to the genus *Diplospora* infest the alimentary tract of these birds. In the main the life-history of a *Diplospora* follows that of an *Eimeria* until sporogony is reached. When this occurs, two sporoblasts only are produced and develop into sporocysts. But within each sporocyst four sporozoites differentiate, so that in the end each oöcyst gives rise to eight sporozoites as in *Eimeria*, but the method whereby the result is attained is of a slightly different type.

*Eimeria stiedae* (Lindemann), variously known as *E. cuniculi*, *Coccidium oviforme*, and *C. perforans* is the pathogenic agent of heavy mortality among rabbits. Coccidiosis in rabbits is often both intestinal and hepatic. Although *E. stiedae* of rabbits resembles, in its morphology and life-history, *E. avium*, yet it is not the same parasite, as some American investigators have asserted. I have shown experimentally that if infected faeces of rabbits, containing many cysts of *E. stiedae* be fed to fowl chicks or young pigeons, the cysts merely pass through the alimentary tract of the birds practically unchanged, and the young birds do not develop coccidiosis.

A few cases of coccidiosis in man have been recorded. It is usually considered that the parasite is *E. stiedae*, derived from rabbits.

Coccidiosis may be a serious pest to cattle.

## X.—CONCLUDING REMARKS.

From the foregoing the importance of coccidiosis in relation to mortality among birds, and especially young birds, can be well estimated. In England, where owing to the development of motor traffic, the character of the country side is rapidly becoming altered, and the air is now polluted with the impalpable dust arising therefrom, the problem of "white diarrhœa" and other forms of coccidiosis seems to be becoming more acute. It is highly important, then, to take every precaution to prevent pollution of air or soil by Coccidian oöcysts, and to adopt any conditions which, by raising the general vitality of the birds, render them the better able to resist the onset of disease.

Preventive measures, so far as our present knowledge goes, have been discussed in Section VIII. (pp. 91-94). For the stamping out of the disease, at any rate among birds under confined conditions, the strictest possible attention must be given to the thorough cleanliness both of the young birds and their surroundings. It is probable that by such preventive measures the disappearance of coccidiosis may be attained in the future.

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## NOMENCLATURE OF ECONOMIC INSECTS.\*

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IN 1908, I wrote a paper for the *Journal of Economic Biology*,<sup>1</sup> in which I suggested certain measures for securing uniformity of nomenclature in economic entomology and gave reasons for doing so. I wish now to follow up the suggestions and to suggest a definite scheme whereby we may make an organised effort to secure this object, in view mainly of the fact that the International Congress meets next year at Oxford, and if this association can make the start and do the preliminary spade work, we may have a good solid basis of work to go on.

I may remind you that the nomenclature of our insects is constantly changing in uniformity with the rules of priority adopted by the body of zoologists.

This is being done in two ways:—

(1) Work on the types proves that certain genera and species, described we will say in the 19th century, were really described by Linnaeus and others in the 18th, thereby altering the designation of that species, of that genus and of that family in some cases.

(2) The splitting of a large genera into smaller ones as more material accumulates and the groups are revised.

These changes are a natural result of researches into types and of our growing knowledge particularly of the fauna of places not hitherto well investigated; they are inevitable, and the progress of economic entomology depends as much upon this work as on any other. We have no quarrel with those who do this and who, rightly, conform to the international agreements on the question of nomenclature. But the changes entail immense confusion, and there are now arising a mass of new names for well-known pests which makes reference to the literature an impossibility unless we also keep up with the changes of nomenclature, which few of us can do. To workers, to teachers, to students, the growing confusion entails an

\* Read before the Association of Economic Biologists, Birmingham Meeting, April 7th, 1911.

<sup>1</sup> Priority and Practical Entomology. *Journ. Econ. Biol.*, 1908, vol. iii, part iv. [*JOURN. ECON. BIOL.*, July, 1911, vol. vi, No. 3.]

intolerable burden, and it is made worse because there are no means of ensuring that all workers either do or do not adopt the changes.

In the case of *Coccidae*, for instance, *Dactylopius* was formerly used for the mealy bugs, but is now for the cochineal insects; a writer nowadays may use *Dactylopius* for either, and you have to find out which he means before you can follow him.

I will quote a number of instances:—

<i>Lita solanella</i>	...	=	<i>Phthorimaea operculella</i> .
<i>Gelechia</i> (part)	...	=	<i>Sitotroga</i> .
<i>Bruchus obtectus</i>	...	=	<i>Acanthoscelides</i> o.
„ <i>lentis</i>	...	=	<i>Laria</i> l.
„ <i>chinensis</i>	...	=	<i>Pachymerus</i> .
„ <i>trifolii</i>	...	=	<i>Bruchidius</i> .
<i>Doryphora decemlineata</i>		=	<i>Leptinotarsa</i> d.
<i>Hypothenemus eruditus</i>		=	<i>Stephanoderes hispidulus</i> .
<i>Xyleborus pubescens</i>	...	=	<i>X. affinis</i> .
<i>Cecidomyia destructor</i>	...	=	<i>Mayetiola</i> d.
* „ <i>leguminicola</i>		=	<i>Dasyneura</i> l.
<i>Tephritis cerasi</i>	...	=	<i>Rhagoletis</i> c.
<i>Trypeta pomonella</i>	...	=	„ p.
<i>Anthomyia brassicae</i>	...	=	<i>Pegomya</i> b.
<i>Phytoptus</i>	...	=	<i>Eriophyes</i> .
<i>Tomicus</i>	...	=	<i>Ips</i> .
<i>Scolytus</i>	...	=	<i>Eccoptogaster</i> .
<i>Epacromia dorsalis</i>	...	=	<i>E. tamulus</i> .
<i>Calandra</i>	...	=	<i>Sitophilus</i> .
<i>Hieroglyphus furcifer</i>	...	=	<i>H. banian</i> .
<i>Pachytylus</i>	...	=	<i>Locusta</i> .
<i>Acridium septemfasciata</i>		=	<i>A. purpuriferum</i> .
<i>Acridium</i> (part)	...	=	<i>Cyrtacanthacris</i> .
<i>Gryllotalpa</i>	...	=	<i>Curtilla</i> = <i>Scapteriscus</i> .
<i>Psocus</i>	...	=	<i>Atropos</i> = <i>Troctes</i> .
<i>Pentatoma</i>	...	=	<i>Cimex</i> .
<i>Cimex</i>	...	=	<i>Acanthia</i> = <i>Klinophilos</i> = <i>Clinocoris</i> .
<i>Pyrilla lycoides</i>	...	=	<i>Zamila aberrans</i> .
* <i>Macrosiphum pisi</i>	...	=	<i>Nectarophora destructor</i> .
<i>Lecanium</i>	...	=	<i>Coccus</i> .
<i>Dactylopius</i>	...	=	<i>Pseudococcus</i> .
<i>Coccus</i>	...	=	<i>Dactylopius</i> .
<i>Mytilaspis</i>	...	=	<i>Lepidosaphes</i> .
<i>Lecanium</i> (part)	...	=	<i>Saissetia</i> .
<i>Mytilaspis pomorum</i>	...	=	<i>Lepidosaphes ulmi</i> .
„ <i>citricola</i>	...	=	„ <i>beckii</i> .

<i>Heliothis armigera</i>	...	=	<i>Chloridea obsoleta</i> .
<i>Agrotis</i> (part)	...	=	<i>Euxoa</i> .
<i>Prodenia littoralis</i>	...	=	<i>P. litura</i> .
* <i>Euplexia conducta</i>	...	=	<i>Perigea capensis</i> .
* <i>Caradrina exigua</i>	...	=	<i>Laphygma exigua</i> .
<i>Aletia xyliana</i> ...	...	=	<i>Alabama argillacea</i> .
<i>Leucania</i> ...	....	=	<i>Cirphis</i> = <i>Heliophila</i> .
* <i>Nonagria</i> ...	...	=	<i>Sesamia</i> .
<i>Orgyia</i> ...	...	=	<i>Hemerocampa</i> .
<i>Euproctis</i> ...	...	=	<i>Porthesia</i> .
<i>Porthetria</i> ...	...	=	<i>Ocneria</i> .
<i>Liparis</i> ...	...	=	<i>Psilura</i> .
<i>Protoparce carolina</i>	...	=	<i>Phlegethontius sexta</i> .
" <i>celeus</i>	...	=	" <i>quinquemaculata</i> .
" <i>convolvuli</i>	...	=	" <i>c.</i> = <i>Herse c.</i>
<i>Sylepta multilinealis</i>	...	=	<i>S. derogata</i> .
<i>Aegeria cucurbitae</i>	...	=	<i>Melittia satyriniformis</i> = <i>M. ceto</i> .
<i>Grapholitha</i> ...	...	=	<i>Enarmonia</i> .
<i>Cemiosstomum coffeellum</i>	=		<i>Leucoptera c.</i>

*Families:—*

<i>Acridiidae</i> ...	...	=	<i>Locustidae</i> .
<i>Locustidae</i> ...	...	=	<i>Phasgonuridae</i> .
<i>Gryllidae</i> ...	...	=	<i>Achetidae</i> .
<i>Scolytidae</i> ...	...	=	<i>Ipidae</i> .
<i>Bruchidae</i> ...	...	=	<i>Lariidae</i> .
<i>Pentatomidae</i>	...	=	<i>Cimicidae</i> .
<i>Cossidae</i> ...	...	=	<i>Zeuzeridae</i> .
<i>Nemeobiidae</i> ...	...	=	<i>Lemoniidae</i> = <i>Erycinidae</i> .
<i>Lymantriidae</i>	...	=	<i>Liparidae</i> .
<i>Malacodermidae</i>	...	=	<i>Cantharidae</i> .
<i>Trogositidae</i> ...	...	=	<i>Temnochilidae</i> = <i>Ostomidae</i> .
<i>Parnidae</i> ...	...	=	<i>Dryopidae</i> .
<i>Ptinidae</i> ...	...	=	<i>Anobiidae</i> .
<i>Cistelidae</i> ...	...	=	<i>Alleculidae</i> .

\* These changes are, in my opinion, necessary.

What I propose is that we endeavour to meet this difficulty by making a standard catalogue of the important species with the name most in use in biologist literature definitely decided on, so that the further changes in nomenclature need not effect us, and so that the systematists and others may have one name to refer to which will cover the economic literature. I propose also that we definitely settle on the names of families, as unit divisions as it were.

The guiding principles I would suggest are as follows :—

1. In view of the constant changing of familiar names of pests, in accordance with the rules of priority, a permanent nomenclature is required for insects of economic importance on which there is a literature.

2. This nomenclature should be independent of and unaffected by the rules of priority.

3. It should be based on the name used in important biological literature, notably that which contains an account of the life-history, habits, and economic importance.

4. Genera in which there is a close uniformity of habits and life-history or which form a distinct class of pest shall, for this purpose, be retained whole and not be sub-divided. (Ex. *Lecanium*, *Dactylopius*, *Agrotis*, *Gryllotalpa*).

5. The constitution and names of families to be retained, the latter not being influenced by changes of nomenclature of type genera.

6. It is recognised that when a stable nomenclature shall be adopted by systematists, the possibility of unifying the economic and the systematic nomenclatures shall be considered.

7. If agreement cannot be obtained among economic entomologists it is hoped that all will at least use the double nomenclature, putting the Standard Economic with the systematic when they differ. (Ex. *Alabama* (Aletia) *argillacea* (xylina).

8. In the case of those pests of which an account is written for the first time, in an accessible publication, replacing notes or references only in an inaccessible one, the name used in the former, whether accurate at the time or not, shall be adopted. (Ex. *Synclera multilinealis* in *Ind. Mus. Notes* in 1890 gives way to *Sylepta derogata* in *Mem. Agric. Dept. India* in 1908).

9. The guiding principle is to make the existing and future biological literature accessible by adopting and making permanent the name under which it was written, and is not to perpetuate inviolate the author of a name or description as in the systematic literature.

10. Whenever possible the existing popular names in the English, French, and German languages shall also be recorded with the Standard Economic, with a view to fixing them.

Now to do this will involve a great deal of work by someone, and I have not come here to make suggestions which I am not prepared to carry out as far as I am able to. The easiest way to carry out this scheme seems to me to be :—

(1) To catalogue the species of insects, etc., which have a definite economic importance as affecting :—

- (a) Crops.
- (b) Forests.
- (c) Domestic animals.
- (d) Stored produce.

Recording the name under which these species are known in the important literature.

(2) To refer these catalogues to the workers in the subject in each country for their opinion and suggestion.

(3) To collate the suggestions and prepare a revised catalogue.

(4) To submit that at the next Annual Meeting, with a view to suggesting action at the International Congress of Entomology in 1912.

I suggest that this Association elect a Committee to carry this out, authorising the preparation of the catalogue, the preparation of a list of persons to whom it should be submitted, the printing of sufficient copies for that purpose, and the collation and preparation of a final catalogue to be submitted at the next annual meeting.

I have at present a card-catalogue of the more important species of crop pest derived from the existing literature; I do not pretend that this list is complete, but I think it could soon be made reasonably complete and ready for submission, if the members of the committee could revise it for this country and Europe, and could prepare a list of workers to whom we would submit it. The actual collation of their suggestions could be done fairly quickly, and I think the list could be prepared by next March. I am not clear as to how we can pay for printing and postage, which is the only expenditure required, but I hope that the Association can meet the difficulty.

This list would cover only the crop-pests, and I think we might find it possible to do this only; the question of doing it also for forest pests for instance is a large one, and I think we might consider how far that could be done or left to the Committee to do what they could.

So also for pests of stored produce and cattle; the former is easy, I think, and could be done quickly; the latter again requires consideration, as it is not quite clear at first sight where that would lead us to; it might lead us into insects carrying disease, and I am not sure that we could carry this all through in the time.

With regard to the crop-pest list, I do not suggest our listing all species attacking every plant of economic value; it would doubtless be useful, but I think we shall do well at first to try to keep out the

unimportant pests; in a paper on the insects of the olive, Ribaga cites 63 species; of these I imagine only perhaps seven as being really important.

I hope I have made clear what I mean and, before proposing any definite resolution, I think that the question should be thoroughly discussed. I foresee many difficulties, but I think we can meet them, and I am convinced that we shall be undertaking a piece of work that will be of practical use, and which is, I consider, one that only this Association can, so far as this country is concerned, carry into effect.

## REVIEWS.

**Austen, E. E.**—A Handbook of the Tsetse-Flies (Genus *Glossina*). Pp. x + 110, 10 pls. and 24 figs. London: 1911. Published by the Trustees of the British Museum. Price 5s. 6d.

Detailed descriptions and accurate figures of those insects concerned in the dissemination of disease are yearly becoming more and more important to Colonial Medical Officers and others, and the present work will be welcomed by such officials in Tropical Africa, as a valuable aid in recognizing and accurately identifying the Tsetse-flies found in their districts.

The author informs us in his introduction that eight years have elapsed since the publication of his "Monograph of the Tsetse-Flies," which work contained descriptions and figures of seven species. At that time the connection between *Glossina palpalis* and Sleeping Sickness was not established, and practically nothing was known as to the habits of that particular species. Much progress has been made even in so short a space of time, but there is still a wide field for further investigation and observation.

In the "Handbook" before us fifteen species are treated of, two of which are new. We are no longer compelled to form our ideas of the Genus upon the life-history and habits of one particular species, as is evidenced by Mr. Austen's excellent chapters on the general characteristics and distribution, and the external characters of the Genus.

The Genus is divided into four Groups, viz., the *palpalis*, *morisitans*, *fusca*, and *brevipalpalis* Groups, and Tables for the determination of these and their included species are given. These are followed by detailed descriptions of each species, with remarks on the bionomics, distribution, and affinities and distinctive characters.

Under distribution we note the absence of any reference to Mr. S. A. Neave's paper on the distribution of *G. palpalis* (Journ. Econ. Biol., 1909, vol. iv).

The work is beautifully illustrated both by coloured plates and text figures.

We congratulate the author on the completion of an exceedingly useful and interesting piece of work, and our National Museum in publishing the same.

W. E. C.

**Miall, L. C.**—History of Biology. Pp. vii + 151, 10 figs. London: Watts and Co., 1911. Price 1s. net.

Professor Miall has written an interesting little work, and our only regret on laying it down is that there is not more of it. It is a masterpiece of succinctness, but we should have liked to know more.

After a brief introduction, he divides his work up into five periods, and reviews in each the chief characteristics and discoveries, incidentally giving us various interesting biographical details of the leading workers. It is an admirable piece of work, serving as an introduction to a vast subject, and written in a delightfully fresh style.

W. E. C.

**Morgan, C. L.**—Animal Biology. Fourth ed., revised. Pp. viii + 416, 144 figs. London: Longmans, Green and Co., 1911. Price 8s. 6d.

Professor Morgan's text-book is too well known to require recommending, and the fact that it has become necessary to issue a revised edition of the fourth edition speaks itself for its retention by many teachers.

We note with satisfaction that the author has reintroduced from an earlier edition, chapters or sections dealing with the Codfish, the Cockroach, the Snail, the Liver-Fluke and the Tapeworm. The work still, however, lacks any account of so important a group of animals as Nematodes.

A new chapter on evolution and heredity has been introduced, which will serve as a useful introduction to the subject for the student.

In its new and revised form the work will no doubt enjoy as wide a circulation and popularity as its predecessors have each done.

W. E. C.

**Stevens, F. L., and J. G. Hall.**—Diseases of Economic Plants. Pp. x + 513, 203 figs. New York: The Macmillan Company; London: Macmillan and Co., Ltd., 1910. Price 8s. 6d. net.

We are informed in the preface of this work that it is designed to meet the needs of "those who wish to recognize and treat disease, without the burden of long study as to their causes; and those who desire to study the etiology of diseases, and to become familiar with the parasites which are often the cause." In our opinion the authors have failed to meet either of these needs; nevertheless, they have produced an interesting and very useful little handbook.

The early chapters are devoted to a consideration of the historical side, the damage caused by plant diseases, the symptoms of disease, the prevention and cure of plant diseases, public plant sanitation, fungicides,

spraying machinery, the costs of and profits from spraying, and soil disinfection.

The bulk of the work is devoted to short, indeed often very scrappy, descriptions of the diseases attacking special crops, and practical directions as to the remedial measures to be applied.

We cannot congratulate the authors on their attempt to make "popular" names derived from the scientific name of the genus of the fungus giving rise to the disease, a feature certainly out of place in a book of this character.

The illustrations are numerous and good.

W. E. C.

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